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Application of Gravitational Search Algorithm and Fuzzy For Loss Reduction of Networked System Using Distributed Generation

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Abstract: *The insertion of distributed generator (DG) into distribution systems for performance improvement has been an obvious application. But the choice of DG has been extended to the networked systems as well in the recent years. The penetration level of DG is accelerating due to the liberalization of electricity markets and Technological advances in small generators and energy storage devices. In this paper the DG technology is used for loss reduction in the networked system. Functioning of DG is effective not merely on DG itself, but through proper location and size of the same. In this paper optimal magnitude of power from DG is computed by using a new algorithm (i.e. Gravitational Search Algorithm (GSA)), upon finding optimal locations through fuzzy inference system. The proposed combination of GSA and Fuzzy concept is tested on an IEEE 5 bus system, IEEE 14 bus system and 62-bus practical Indian system.*
Keywords: *Distribution Generation, Fuzzy Approach, Gravitational Search Algorithm*

I. Introduction

Distributed Generation(DG) is utilised a power supply in distribution systems which was extended to power transmission system for - choking transmission loss, improving voltage profile, and reducing the congestion etc. The integration of DG with the utility system at permissible voltage involves usage of small scale distributed energy resources. DG mainly constitutes non-conventional and renewable energy sources like solar PV, wind turbines, etc. [1]

DG involves the interconnection of small-scale distributed energy resources with the main power utility at distribution voltage level [2-4]. DG can reduce power loss and can improve node voltages. Further power loss lowering can be at expense of worse voltage profile and vice versa [5]. These two main outcomes should be compromised to get an optimal overall performance. Here these effects are highly dependent on DG allocation in the transmission or distribution system. So the sizing and locations of DG have to be computed carefully to optimize the overall Performance, which will result in technical and economic benefits [6-7].

In this paper section II describes the Fuzzy approach for DG optimal locations which rely on loss and voltage indices. Section III describes the methodology for DG sizing using GSA. Section IV presents the result analysis and discussion for the proposed concept.

II. Fuzzy Approach For Optimal DG Locations

Fuzzy logic is a technique that allows for quantification and processing of common language rules to arrive at a decision. Al1 the rules are considered at once or in parallel to arrive at a weighted decision [8-9]. In this paper the basics of applying the fuzzy logic method is for finding optimal locations of DG. Newton-raphson method is used for load flow study, which was applied on IEEE 5 bus system, IEEE 14 bus system, and 62 bus Indian practical systems.

2.1 Loss index

In this index the real power loss reduction is observed when total load is completely or partially removed at a particular load bus. The loss index is determined using (1).

$$LI = P^1 - P^2 \tag{1}$$

Where,
LI = Loss Index
P^1 = Power loss for normal load
P^2 = Power loss for partial load

The above obtained loss reductions are then, linearly normalized into a [0, 1] range with the largest loss reduction having a value of 1 and the smallest one having a value of 0. The normalised loss index is given as one of the two indexes to the fuzzy inference system.

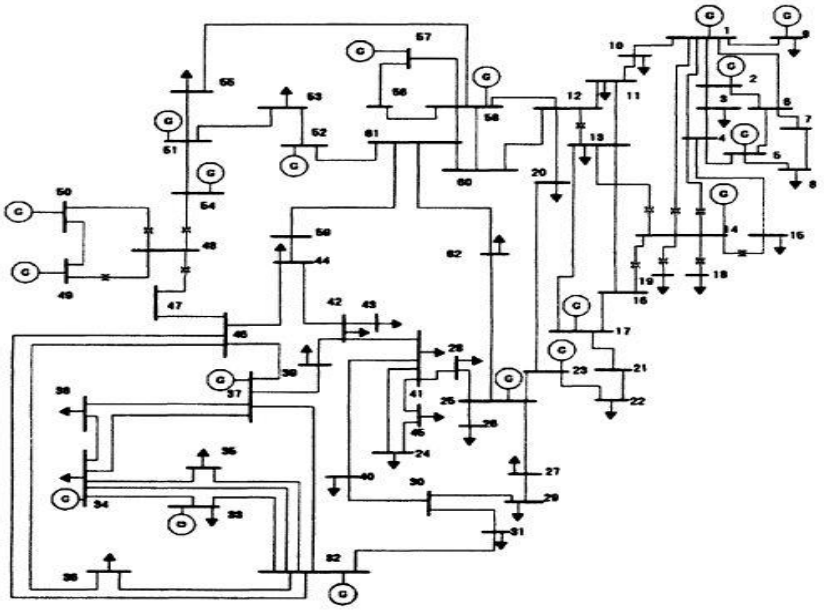

Figure 1: One line diagram of Indian 62-bus practical system

2.2 Voltage Index

This index is taken as a second input to the fuzzy inference system, here the voltages are also normalized into a [0, 1] range with the largest voltage having a value of 1 and the smallest one having a value of 0.

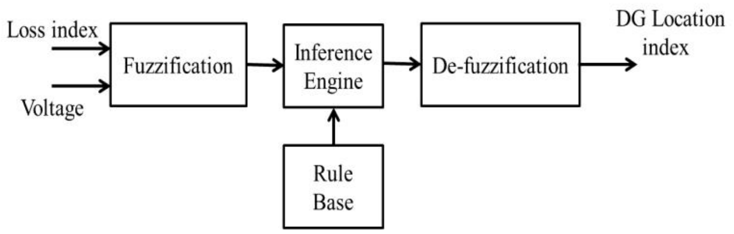

Figure 2: Block diagram of Fuzzy inference system

Rule base and the membership function for the inference system shown in Fig. 2 were adopted from [10]. The DG location index obtained from the inference system will be considered as optimal locations for DG in priority wise i.e. index nearing 1 will be best, and for 0 it will be worst case.

III. Methodology For Calculating Sizing Of DG

Gravitational Search Algorithm (GSA) is proposed by Esmat Rashedi et al in 2009[11], which is rely on law of gravity and mass interactions. In this algorithm, the searcher agents are a collection of masses which interact with each other based on the Newtonian gravity and the laws of motion.

In GSA, each position of mass (agent) has a solution, wherein the position of heaviest mass has optimum solution which attracts other masses, by proper acceleration of their gravitational and inertia masses. At the end iteration count the heaviest mass will present an optimum solution in the search space. In this study GSA is used for optimizing the capacity of DG by randomly generating the masses between prescribed limits.

Algorithm for DG sizing using GSA

Step 1: Initially [nom x n] number of masses are generated randomly within the limits, where 'nom' is the population size and 'n' is the number of DG units. Each row represents one possible solution to the optimal DG-sizing problem.

Step 2: Similarly [nom x n] number of initial velocities is generated randomly between the limits. Iteration count (T) is set to one.

Step 3: Calculate the force on the **i^{th}** mass by the remaining other masses using (2)

$$F_{ij} = G \times \frac{M_p \times M_a}{R_{ij} + \varepsilon} \times \left(DGx_j^d - DGx_i^d\right) \quad (2)$$

Where,
M_{aj} = Active gravitational mass related to agent j, M_{pi} = Passive gravitational mass related to agent i,
G = Gravitational constant,
ε = Small constant, and
R_{ij} = Euclidian distance between two agents i and j:

$$R_{ij} = \left\| DGx_i, DGx_j \right\|_2 \tag{3}$$

The total force that acts on i^{th} mass in a dimension **d** be a randomly weighted sum of $\mathbf{d^{th}}$ components of the forces exerted from other agents.

$$F_i^d = \sum_{i=1, j \neq i}^{N} rand_i .\ F_{ij}^d \tag{4}$$

Where, rand = random number generated between 0 and 1.

Step 4: After finding the net force on each mass due to the other masses, the acceleration for each mass is calculated using (5)

$$a_i^d = \frac{F_i^d}{M_i} \tag{5}$$

Step 5: The velocities and position of all the masses are updated using (6), (7)

$$V_i^d = rand_i \times V_i^d + a_i^d \tag{6}$$

$$DGx_i^d = DGx_i^d + V_i^d \tag{7}$$

Step 6: Fitness values of all the masses are calculated
Step 7: Set error tolerance (e) = 0.0001, if 'e' is greater than the difference of best of fitness matrix and mean of fitness matrix, then go to Step 8, else go to Step 9.
Step 8: The current iteration (T) count is incremented and if 'T' is not reached maximum then go to step 3
Step 9: The heaviest mass in the population gives the best fitness value i.e. maximum loss reduction and position of that mass gives the optimal DG sizes.

IV. Result And Discussion

The proposed concept which is a two – stage methodology has applied on standard IEEE systems as well on Indian practical system.

IEEE 5 bus system [12] contains 1 slack/generator buses (bus numbers: 1,), 4 load buses (bus numbers: 2, 3, 4, and 5) and 7 transmission lines. Fuzzy approach gives 3^{rd} location as optimal choice, where GSA optimized the sizing of DG with which the losses in the system has reduced significantly and voltage profile has increased significantly.

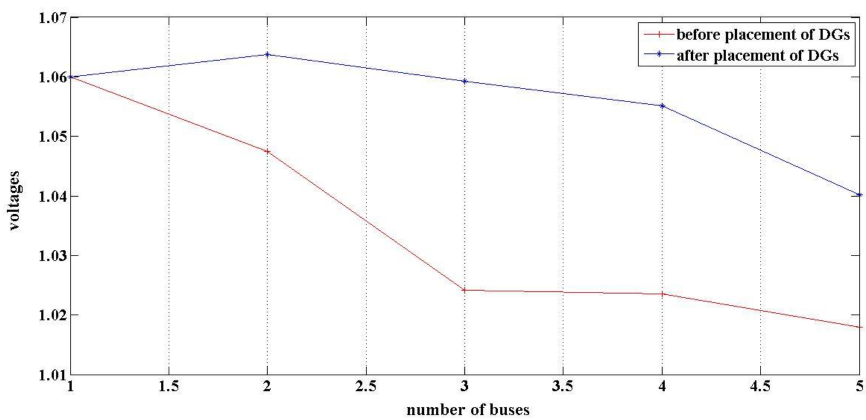

Figure 3: Voltage profile before and after DG placement for IEEE 5 bus system

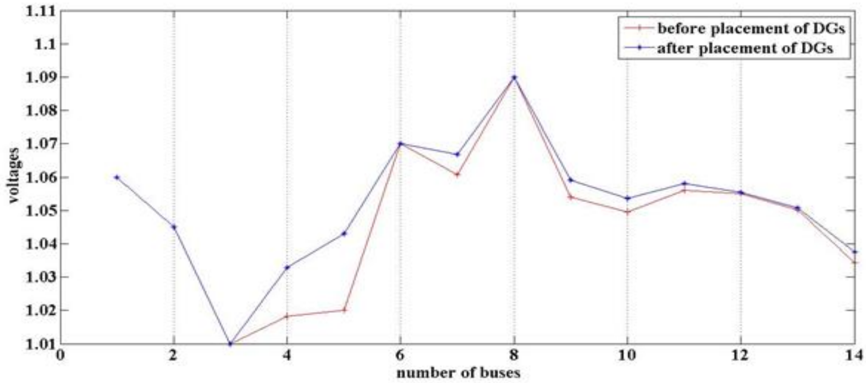

Figure 4: Voltage profile before and after DG placement for IEEE 5 bus system

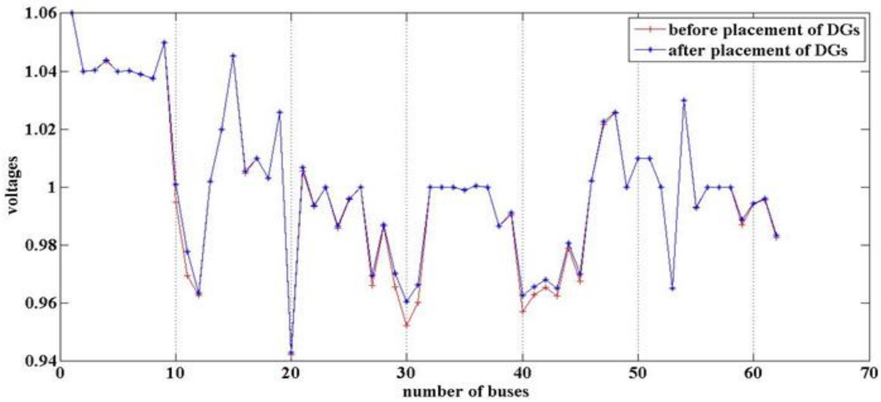

Figure 5: Voltage profile before and after DG placement for Indian 62 bus practical system

Table 1: Total Loss before and After Placement of DG using GSA

Test System Used	Optimal Location by Fuzzy Approach	Total Loss Before DG Placement (MW)	Iterations generated	Optimized Capacity of DG (MW)	Total Loss After DG Placement (MW)
IEEE 5 bus system	3	4.5868	32	108.0316	1.3231
IEEE 14 bus system	5	13.3934	33	178.8503	5.2879
Indian 62 bus Practical system	11, 30	64.0512	30	101.7489, 76.9365	60.2518

IEEE 14 bus system [13] contains 5 generator buses (bus numbers: 1,2,3,6 and 8), 9 load buses (bus numbers: 4, 5, 7,9,10,11,12,13 and14) and 20 transmission lines. Fuzzy approach gives 5th location as optimal choice, where GSA optimized the sizing of DG with which the losses in the system has reduced significantly and voltage profile has increased considerably.

Indian 62 bus practical system [14] contains 19 generator buses (bus numbers: 1, 2, 5, 9, 14, 17, 23, 26, 32, 33, 34, 37, 49, 50, 51, 52, 54, 57, and 58), the remaining are load buses and 89 transmission lines. Fuzzy approach gives 11th and 30th location as optimal choice, where GSA optimized the sizing of DG in both the locations with which the losses in the system has reduced considerably and voltage profile has increased a little on some buses.

V. Conclusion

The proposed concept has been successfully applied on IEEE 5 bus, IEEE 14 bus and Indian practical system. The Fuzzy approach has given best locations (based on index calculated), for installation of DG. For sizing of DG the Gravitational Search Algorithm optimized accurately for best loss reduction and better voltage profile.

When compared the results obtained for IEEE standard systems and Indian practical systems, the effective ness of DG on both the systems is not same, because the real systems are complicated having more uneven transmission lines with different loading conditions. To some extent, application of DG is a good option for loss reduction in real system.

Every optimization technique when verified on standard test functions will converge perfectly irrespective of time consumed. A optimization is said to be a better one based on the computation time required, here GSA is a best technique which take less time, because the masses are updated by taking the cumulative difference of all masses available, whereas in standard PSO, Firefly Algorithm etc. each particle is been updated with reference to the global best practical.

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